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**BODY PROBE FOR MRI AND MRI APPARATUS****BACKGROUND OF THE INVENTION****Field of the Invention**

5 The present invention relates to a body probe for MRI and an MRI apparatus using the probe, and, more particularly, to a body probe for MRI which is easy to use and provides clear images without image degradation and an MRI apparatus using the probe.

10 **Description of the Related Prior Arts**

In general, a body probe for MRI comprises two reception coils that are to be positioned above and under a subject to be examined (examinee). A typical body probe for MRI according to the related art has upper and lower coils formed integrally into a cylindrical shape or a cylindrical shape which can be partly opened sideways, or a belt-like shape.

15 FIGS. 11A and 11B are diagrams for explaining one structural example of a body probe for MRI according to the related art. Referring to the figures, "111" denotes a body probe, "112" denotes a body portion and "113" is a window.

20 The body probe 111 according to the related art exemplified in FIGS. 11A and 11B has a cylindrical shape. As shown in FIG. 11A, the body probe 111 comprises the cylindrical body portion 112 which has a length and internal vertical and horizontal sizes long and large enough to cover the chest of a subject to be

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examined. The windows 13 are formed in the top and bottom portions of both sides of the body portion 112 in order to lighten the entire weight of the body probe and permit the position of the subject with respect to the body probe to be checked from outside. Though unillustrated, reception coils are embedded in the body portion 112 and are connected to an MRI apparatus so that signals from the coils are processed to form an image to be displayed.

FIG. 11B shows how the cylindrical body probe 111 according to the related art is used. A subject to be examined whose chest is enclosed by the body probe 111 is placed inside an MRI apparatus for examination. Generally speaking, the size of the chest varies from one person to another. It is therefore difficult to prepare a probe which matches with the size of the chest of each subject, and such an attempt inevitably results in an increase in the cost of the entire MRI system. In this respect, normally, three or so different sizes of body probes 111 are prepared and used for all subjects of different builds.

Although the body probe exemplified in FIGS. 11A and 11B is designed completely cylindrical, there is a body probe designed in such a way that it can be opened sideways at the center portion.

FIG. 12 is a diagram for explaining another structural example of the body probe for MRI according to the related art. In FIG. 12, "121" is a bore, "122"

is an upper coil, "123" is a lower coil, "124" is a belt, "125" denotes cords, and "126" is a connector box.

The body probe for MRI exemplified in FIG. 12 has reception coils which comprise the upper coil 122 and the lower coil 123. In using the body probe, the lower coil 123 and the upper coil 122 are secured by the belt 124, the former placed under the back of a subject to be examined and the latter over the abdominal portion, the chest or the like of the subject. The belt 124 is attached to a belt groove provided in the frame of a bed in such a way as to be movable along the bed to secure a desired portion of the subject. The belt 124 is movable in accordance with the mount position of the upper coil 122. The body probe for MRI according to the related art which has the above-described structure can securely fix the upper coil 122 and the subject together.

The cords 125 that extend from the upper and lower coils run along one edge portion of the bed and are connected to the connector box 126 located inside the bore 121 of the MRI apparatus. At the time of picking an image with the MRI apparatus, the subject is fed into the bore 121 to a predetermined position together with the top table of the bed and the connector box 126.

The cylindrical body probe for MRI according to the related art does not have fixed distances between the subject and the coils in the body probe due to a

difference in the build of the subject and has a difficulty in securing the subject inside the body probe. This makes the characteristics of the coils instable, so that the picked-up image of the subject is degraded by the movement of the body of the subject. The cylindrical body probe also has a shortcoming such that it is not easily attached to a subject.

Another body probe for MRI according to the related art whose reception coils comprise an upper coil and a lower coil has no coil portions provided at portions corresponding to the sides of the subject. In addition, it is difficult to place the center of the upper coil over the center of the body axis of the subject, so that the center of the upper coil may be misaligned with the center of the body axis of the subject. This makes it difficult to acquire clear images.

With regard to the belt-like body probe according to the related art, one among several sizes of body probes which matches with the build of a subject to be examined is selected and is fitted on the subject. This type cannot suppress the movement of the body of the subject, so that the body probe moves as the body of the subject moves. This also leads to image degradation.

The reception coils according to the related art are cylindrical or belt-like and their sizes are not prepared subject by subject. Rather, one among

several sizes of body probes prepared which is closer to the build of a subject to be examined is selected. As the shapes of the reception coils become closer to the shape of the subject, the sensitivity becomes higher. To achieve a high sensitivity, therefore it is necessary to fit the reception coils closely to the subject. On the contrary, the reception coils according to the related art are difficult to be fitted closely to each subject to be examined.

#### SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide an easy-to-use body probe for MRI which overcome the aforementioned problems of the related art, is easily attached to various subjects to be examined who have different sizes of builds and does not suffer image degradation, and an MRI apparatus which uses this probe.

The object is achieved by designing a body probe for MRI having reception coils for picking up an image for use in an MRI apparatus in such a way that the reception coils are provided in a center coil portion and two side coil portions.

The object is achieved by providing slide mechanisms of the side coil portions, which are formed by smooth surfaces are formed on both right and left sides of the center coil portion, at joint portions between the center coil portion and the side coil

portions.

5       The object is achieved by designing a bottom surface of the center coil portion in a curved shape, or providing an indicator indicating a center of a center coil at a center of a top surface of the center coil portion. The indicator indicating the center of the center coil may be a groove, a projection or a line drawn in color different from a color around the line.

10       The object is also achieved by designing a body probe for MRI having reception coils for picking up an image for use in an MRI apparatus in such a way that the reception coils are provided in a center coil portion, side coil portions and a base coil portion. The center coil portion, the side coil portions and the  
15       base coil portion may be constructed independently of one another.

20       The object is achieved by constructing the side coil portions by embedding a flexible coil in a soft member or providing the side coil portions with cutaway holes at portions where there are no coil portions.

25       The other objects and structures of the invention and the resulting advantages will become apparent from the following detailed description of an embodiment of the invention.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

FIGS. 1A and 1B are perspective views showing the outward appearance of a body probe for MRI

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according to one embodiment of the invention;

FIG. 2 is a diagram showing side coil portions of the body probe for MRI according to the embodiment of the invention opened;

5           FIG. 3 is a diagram for explaining the procedures of fitting the body probe according to the embodiment of the invention to a subject to be examined;

10           FIG. 4 is a diagram for explaining the state in which the body probe according to the embodiment of the invention is fitted on the subject (examinee);

FIG. 5 is a diagram for explaining how the side coil portions are deformed;

15           FIG. 6 is a diagram for explaining another means for fitting the center coil portion on the subject;

20           FIGS. 7A and 7B are diagrams for explaining the basic shapes of coils formed in individual coil portions according to the embodiment of the invention and the shape of a coil formed in a head coil portion;

FIG. 8 is a diagram for explaining the shape of a coil formed in a side coil portion;

FIG. 9 is a diagram for explaining the shape of a coil formed in a base coil portion;

25           FIG. 10 is a diagram for explaining the shape of a coil formed in a center coil portion and the structure of a cable connector;

FIGS. 11A and 11B are diagrams for explaining

one structural example of a body probe for MRI according to the related art; and

FIG. 12 is a diagram for explaining another structural example of the body probe for MRI according to the related art.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the invention is described below with reference to the accompanying drawings.

FIGS. 1A and 1B are perspective views showing the outward appearance of a body probe for MRI according to one embodiment of the invention, and FIG. 2 is a diagram showing the side coil portions of the body probe according to the embodiment of the invention opened. In the diagrams, "11" is a base coil portion, "12" is a side coil portion, "13" is a center coil portion, "14" is a head coil portion, "15" is a head holder, "16" is a fixing band, "17" is a coil cable, "18" and "19" are cutaway holes, "20" is a center indicator portion, "21" is a cable connector, "22" is a fixing-band groove, "23" is a smooth surface, "24" is a head-coil connecting portion, "25" are side-coil connecting portions, "26" is a connector and "27" is a recess portion.

As shown in FIGS. 1A and 1B (which are perspective views from different viewpoints that will not be distinguished from one another in the following



description) and FIG. 2, the body probe for MRI  
according to the embodiment of the invention comprises  
the base coil portion 11 which is positioned at the  
back portion of a subject to be examined (hereinafter  
5 simply referred to as "subject") when laid down on his  
or her back on an unillustrated bed, the two side coil  
portions 12 which are to be connected to the side-coil  
connecting portions 25 provided on both sides of the  
base coil portion 11, and the center coil portion 13  
10 which connects the two side coil portions 12 at the  
center of the chest of the subject.

The head holder 15 is provided at that portion  
of the base coil portion 11 where the head of the  
subject is to be placed. The head holder 15 holds the  
15 head of the subject in such a way that the subject's  
head does move around. The recess portion 27 where the  
buttocks of the subject will rest is provided at the  
opposite side of the base coil portion 11 to the head  
holder 15. The side-coil connecting portions 25 are  
20 formed on both sides of the base coil portion 11, and  
the side coil portions 12 are to be attached in such a  
way as to be movable at an arbitrary angle with respect  
to the base coil portion 11. This design makes it  
possible to open the side coil portions 12 as shown in  
25 FIG. 2 to facilitate attachment of the body probe to  
the subject at the time of attachment. Further,  
folding the side coil portions 12 inside makes it  
easier to carry the side coil portions 12 around and

can contribute to reducing the storage space therefor. The side coil portions 12 can be detached from the base coil portion 11 at the positions of the side-coil connecting portions 25.

5           Each side coil portion 12 is made of a soft member, such as a rubber-based or urethane based member, and has a band-like conductive member embedded inside. As will be discussed later, therefore, the side coil portions 12 can take shapes which match with the side surfaces of the subject and can be fitted closely on the subject. Even when the subject puts the weight on the side coil portions 12, the soft members used for the side coil portions 12 neither causes a pain on the subject nor damages the side coil portions 12. For the purpose of weight reduction, the cutaway hole 18 is formed in that portion of each side coil portion 12 where the internal coil does not exist. To improve the image quality, that portion of each side coil portion 12 which is to be connected to the center coil portion 13 is designed to be arcuately curved in such a way that the curved portion comes closest to the coil center of the base coil portion 11.

20           Two coil cables 17 having connectors 26 are provided on each side of those portions of the two side coil portions 12 which are to be connected to the center coil portion 13 at the chest of the subject. Provided at the center portions of those portions of the two side coil portions 12 which are to be connected

to the center coil portion 13 at the chest of the subject are the fixing bands 16 for fixing the side coil portions 12 and the center coil portion 13 in close contact with the subject. A cutaway hole 18' is formed in each side coil portion 12 on that side of the base coil portion 11. When the side coil portions 12 are fitted on the subject, portions of the subject can be seen through the cutaway holes 18'. The cutaway holes 18' also serve to improve the ventilation.

The center coil portion 13, which is to be placed at the center of the chest of the subject, has capabilities to couple the two side coil portions 12 together and electrically connect the coils in the coil portions. The center coil portion 13 improves the close attachment to the subject and always stays on the center of the body axis of the subject, so that the constant precision of picked-up images can be maintained. To ensure adequate coil shapes at the time the center coil portion 13 is connected to the side coil portions 12, the bottom surface of the center coil portion 13 is curved to match the shape of the chest of the subject. This design can reduce the sensation of pressure on the subject.

As shown in FIG. 2, the center coil portion 13 is provided with the smooth surfaces 23 on the right and left sides, which constitute slide mechanisms. The center portion of the center coil portion 13 that follows the smooth surfaces 23 is a step portion which

is thicker than the smooth surfaces 23. Provided at the step portion of the center portion are the cable connectors 21 to which the connectors 26 attached to the coil cables 17 of the side coil portions 12 are connected. The center indicator portion 20 that indicates the center is provided at the position of the center portion which becomes the center of the body axis, as a groove, a projection or a line drawn in color different from a color around the line. Further provided in the center portion of the center coil portion 13 in a direction perpendicular to the body axis is the fixing-band groove 22 through which the fixing bands 16 are put.

The head coil portion 14 is suitable for use with the body probe according to the embodiment of the invention. The head coil portion 14, when in use, is coupled to the head-coil connecting portions 24 formed on both sides of the head holder 15. As will be discussed later, the cutaway holes 19 in the head coil portion 14 are provided at the positions of ears of the subject to suppress the sensation of pressure at the time the head coil portion 14 is mounted on the subject and to permit smooth conversation with a caretaker.

FIG. 3 is a diagram for explaining the procedures of fitting the body probe according to the embodiment of the invention on a subject, FIG. 4 is a diagram for explaining the state in which the body probe according to the embodiment of the invention is

fitted on the subject, and FIG. 5 is a diagram for explaining how the side coil portions are deformed. Referring now to FIGS. 3 to 5, the procedures of fitting the body probe on the subject and the fitted state are described below.

With the side coil portions 12 opened sideways and the head coil portion 14 removed as shown in FIG. 2, the subject is laid down on the base coil portion 11 in such a way as to place the subject's head in a cavity of the head holder 15 as shown in FIG. 3. At this time, the buttocks of the subject are positioned in the recess portion 27 of the base coil portion 11. Next, the caretaker places the center coil portion 13 on the chest of the subject and adjusts its position in such a way that the center indicator portion 20 comes to the center of the chest of the subject and the fixing-band groove 22 comes to the position of the fixing bands 16 of the side coil portions 12.

Then, the caretaker turns the two side coil portions 12 inward so as to enclose the chest of the subject and connect the side coil portions 12 without altering the position of the center coil portion 13 by the fixing bands 16. At this time, the distal portions of the side coil portions 12 are placed on the smooth surfaces 23 of the center coil portion 13 and can slide on the smooth surfaces 23 by the tension of the fixing bands 16. Accordingly, the side coil portions 12 which are constructed by embedding band-like conductive

members inside soft members, can be deformed to match the shape of the chest of the subject and put around the chest of the subject tightly as shown in FIG 4.

5       Next, the caretaker attach the head coil  
portion 14 to the head-coil connecting portions 24 on  
the base coil portion 11. As seen from FIG. 4, when  
the head coil portion 14 is attached, the ears of the  
subject come to the positions of the cutaway holes 19  
10       formed in the head coil portion 14. Therefore, the  
subject can hear the ambient sounds without  
interference and can feel relaxed about the examination.

      Surface coils to be discussed later are formed  
inside the side coil portions 12 at portions close to  
the center coil portion 13 and around the cutaway holes  
15       18, protruding in the direction of the shoulders and  
the direction of the waist. Those portions of the side  
coil portions 12 where the surface coils are not  
located are cut away. The subject can therefore put  
the arms out through the cutaway portions loosely, thus  
20       reducing the awkwardness of putting the probe on. The  
coils that are formed to protrude in the direction of  
the shoulders and the direction of the waist can  
provide an image over a wide range.

      Referring now to FIG. 5, a description will be  
25       given of how to deform the above-described side coil  
portions 12 to match the shape of the chest of the  
subject and put them around the chest of the subject  
tightly.

As shown in FIG. 5, the stepped center portion of the center coil portion 13 that follows the smooth surfaces 23 thereof has a total width of 60 mm, 30 mm in either direction from the center indicator portion 20, and the smooth surface 23 that constitutes the slide mechanism on one side has a width of 75 mm. The distal end portion of each of the two side coil portions 12 can move within a range of the 75-mm width of the smooth surface 23. Accordingly, the inner circumferential length that is formed by the base coil portion 11, the two side coil portions 12 and the center coil portion 13 can be adjusted within a range of 150 mm. This state is illustrated in FIG. 5. Therefore, the side coil portions 12 can be deformed to match the size of the chest of the subject and put around the chest of the subject tightly.

As mentioned above, the body probe according to the embodiment of the invention is designed in such a way that a set of one center coil portion 13 and two side coil portions 12 can absorb a difference of 150 mm in the circumferential length of the chest of the subject and the side coil portions 12 can be deformed and put around the chest of the subject tightly. To absorb a difference in the circumferential length of the chest of a larger subject, another center coil portion 13 of a different width size should be prepared. This can allow the body probe of the invention to cope with all types of subjects from a small-sized Japanese

to a large-sized European.

In case of the cylindrical body probe according to the related art, at least three types of body probes, large, intermediate and small ones, should be prepared.

5 By way of contrast, the body probe according to the embodiment of the invention can be used all types of subjects of different builds by merely preparing two types of center coil portions 13.

10 FIG. 6 is a diagram for explaining another means for fitting the center coil portion on the subject. In FIG. 6, "16'" denotes a fixing belt and the other structural elements, which are not given reference symbols, are the same as those explained above with reference to FIGS. 1A, 1B, 2, 3, 4 and 5.

15 The body probe according to the embodiment of the invention that has already been discussed referring to FIGS. 1A, 1B, 2, 3, 4 and 5 is designed in such a way that the side coil portions 12 and the center coil portion 13 are fixed in close contact with a subject by  
20 the fixing bands 16 provided on the side coil portions 12. By way of contrast, the example shown in FIG. 6 is designed in such a way that the fixing belt 16' is attached to the sides of the base coil portion 11. The body probe is attached to the subject by first placing  
25 the center coil portion 13 on the chest of the subject, then securing the center coil portion 13 on the chest of the subject by the fixing belt 16' and then connecting the side coil portions 12 to the center coil



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portion 13 in the same way as has been discussed in the foregoing description.

According to the example shown in FIG. 6, the side coil portions 12 have only to be connected to the center coil portion 13 after the center coil portion 13 is secured on the chest of the subject by the fixing belt 16'. The work of attaching the body probe to the subject becomes easier than the attachment work of securing the side coil portions 12 and the center coil portion 13 together in close contact with the subject merely by the fixing bands 16 involved for the body probe that has already been described referring to FIGS. 1A, 1B, 2, 3, 4 and 5. This feature can relieve a caretaker of the burden.

The foregoing description has explained the embodiment of the body probe for MRI according to the invention. A description will now be given of the shapes of coils formed in the individual coil portions that have already been discussed.

FIGS. 7A and 7B are diagrams for explaining the basic shapes of coils formed in the individual coil portions according to the embodiment of the invention and the shape of the coil formed in the head coil portion. FIG. 8 is a diagram for explaining the shape of the coil formed in the side coil portion, and FIG. 9 is a diagram for explaining the shape of the coil formed in the base coil portion. FIG. 10 is a diagram for explaining the shape of the coil formed in the

center coil portion and the structure of the cable connector. In the diagrams, "71" is a solenoid coil, "72" is a surface coil, "73" is a solenoid coil for cervical vertebrae, "74" is a surface coil for head, "81" is a solenoid coil for lumbar vertebrae, "82" is a solenoid coil for thoracic vertebrae, "83" is a surface coil for lumbar vertebrae, "84" is a surface coil for thoracic vertebrae, and "91" and "92" denote connectors.

According to the invention, as shown in FIG. 7A, the combination of both the solenoid coil and the surface coil is used in picking up the image of a subject's part of interest. The solenoid coil 71 is formed in a loop and is laid out to surround the subject's part to be picked up. The surface coil 72 is formed in the shape of the letter "8" in such a way as to be extendible in a planar pattern in the coil portion. The surface coil 72 is laid along the subject's part to be picked up.

As shown in FIG. 7B, the cervical-vertebrae solenoid coil 73 for picking up the image of the cervical vertebrae is provided in the bridge that is located in the head coil portion 14 at a position close to the neck of the subject. The cervical-vertebrae solenoid coil 73 is connected inside the base coil portion 11 via unillustrated connectors provided in the head-coil connecting portions 24, so that the entire solenoid coil 73 is formed in a loop. The head surface coil 74 is laid around each cutaway hole 19 formed in

the head coil portion 14. The head surface coil 74, like the solenoid coil 73, is connected inside the base coil portion 11 via an unillustrated connector provided in the associated head-coil connecting portion 24, so that the entire solenoid coil 73 is formed in the shape of the letter "8". That internal part of the base coil portion 11 which constitutes a part of the head surface coil 74 has a shape extending long toward the associated shoulder.

As shown in FIG. 8, the lumbar-vertebrae solenoid coil 81, the thoracic-vertebrae solenoid coil 82, the lumbar-vertebrae surface coil 83 and the thoracic-vertebrae surface coil 84 are arranged inside each side coil portion 12. The coils 81 and 82 are used to pick up the images of the lumbar vertebrae and thoracic vertebrae. As in the case of the head coil portion 14, the solenoid coils 81 and 82 are connected inside the base coil portion 11 and the center coil portion 13 to form loops and the surface coils 83 and 84 are connected inside the base coil portion 11 and the center coil portion 13 to form the shapes of the letter "8". That side of each coil which is to be connected to the center coil portion 13 is connected to the connector 26 for connection to the center coil portion 13 via the associated coil cable 17, as has already been explained.

As apparent from the foregoing description, the base coil portion 11 connects the coils provided in the

side coil portions 12 and the head coil portion 14 to form the desired shapes of the solenoid coils and the surface coils. As shown in FIG. 9, coil portions which form the individual coils provided in the side coil portions 12 are laid inside the base coil portion 11. The connection to each side coil portion 12 is accomplished via the connector 91 provided at the side coil portion 12 and the connector 92 provided at the base coil portion 11. Though not illustrated, the coil portions that form the individual coils in the head coil portion 14 are likewise laid inside the base coil portion 11.

As shown in FIG. 10, the cable connectors 21 are provided two on a single circuit board and are provided in the center coil portion 13 in such a way that two cable connectors 21 are positioned on either side of the center portion of the center coil portion 13 that is designed to have a step thicker than the smooth surfaces 23.

Though unillustrated, the individual coils that constitute the body probe and the coils provided in the head coil portion are connected to the body of the MRI apparatus via cables for acquisition of reception signals, so that an image is produced from the reception signals.

According to the embodiment of the invention, the coils are provided in separated plural coil portions and the use of the center coil portion

facilitate the attachment of the coils to a subject in such a way that the center of each coil is always aligned with the center of the body axis of the subject. According to the embodiment of the invention, each side  
5 coil portion is constructed by embedding a flexible coil in a soft member and the position at which the center coil portion is joined to the side coil portions can be slidably adjusted. It is therefore possible to allow the reception coils to be attached to the body of  
10 the subject tightly in accordance with a difference in the build of the subject. This can provide high-precision images.

According to the embodiment of the invention, because the slide adjustment can allow the reception  
15 coils to be attached to the body of the subject tightly, the coil center does not deviate even when the subject moves. As a result, high-precision images can be obtained. As the center coil portion 13 has the portion that permits slide adjustment of the side coil  
20 portions, preparation of two types of center coil portions of different width sizes can allow the body probe to be used for all types of subjects of different builds.

According to the embodiment of the invention,  
25 cutaway holes are formed in those portions of the individual coil portions where there are no coils laid out and the member for molding the coils is a soft member, such as a rubber-based or urethane based member,

it is easy to fit the body probe on the subject and it is possible to improve the sensation of attachment and the feeling of freedom.

As described above, the invention can provide  
5 an easy-to-use body probe for MRI which is easily attached to various types of subjects to be examined and does not suffer image degradation, and an MRI apparatus which uses this probe.

#### **Industrial Applicability**

10 A body probe for MRI according to the invention and an MRI apparatus using the probe can be effectively used in the field of the medical equipment industry.

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